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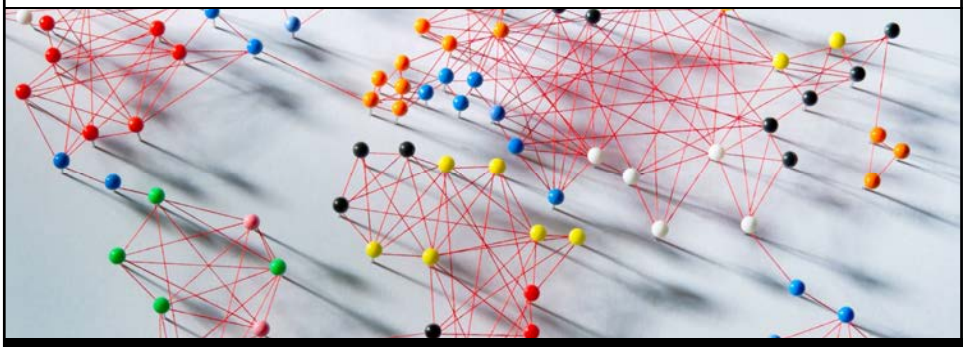

9. Intrusion Detection Sensors

October 24 – November 11, 2016
Albuquerque, New Mexico, USA
Larry Miller

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Learning Objectives

At the end of this module, you should be able to:

- Discuss the role of intrusion detection sensors
- Identify exterior and interior sensors by classification
- Recognize sensor technologies
- Identify characteristics of a good intrusion detection system design
- Discuss performance characteristics of intrusion detection sensors

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Intrusion Detection Sensors

Role of Intrusion Detection

- PPS functions
- Detection
  - Exterior intrusion detection
  - Interior intrusion detection
  - Assessment
  - Alarm communication and display
  - Entry control
- Delay
- Response
- IAEA Nuclear Security Series No. 13 recommends an integrated system of detection, delay, and response

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Intrusion Detection Sensors

Performance Characteristics of Intrusion Detection Sensors

- Probability of Detection (P_D)
  - $P_D = P_S * P_A$
  - where
    - P_S is Probability of Sensing
    - P_A is Probability of Assessment

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Intrusion Detection Sensors

Performance Characteristics of Intrusion Detection Sensors (continued)

- Vulnerability to defeat
  - Bypass: Avoiding the detection volume of the sensor by crawling, jumping, tunneling, or bridging
  - Spoofing: Tricking the sensor into not reporting an alarm
- Methods are dependent on adversary and adversary tactics
  - *Given the proper knowledge, tools, and time, every sensor can be individually defeated*

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Intrusion Detection Sensors

Performance Characteristics of Intrusion Detection Sensors (continued)

- Types of alarms
  - Real Alarms - Caused by an actual intrusion
  - Nuisance Alarms - Occur when the sensor performed properly, but detected something other than a real intrusion attempt
  - False Alarms – Generated by the sensor either because of poor maintenance or equipment failure
- All alarms are considered unknown alarms until they have been properly assessed

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Intrusion Detection Sensors

Exterior Sensor Classifications

- Active or passive
- Covert or visible
- Volumetric or line
- Line of sight or terrain following
- Mode of application
  - Buried line
  - Fence associated
  - Freestanding

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Intrusion Detection Sensors

Perimeter Features

- Defines the boundary of the Protected Area
  - Well-defined clear zone, typically uses two fences
  - Includes sensors, lighting, assessment, access control, and delay features
  - Detects unauthorized access to the Protected Area
- Protected Area is defined in IAEA NSS-13 as an area inside a limited access area containing Category I or II nuclear material and/or sabotage targets surrounded by a physical barrier with additional physical protection measures

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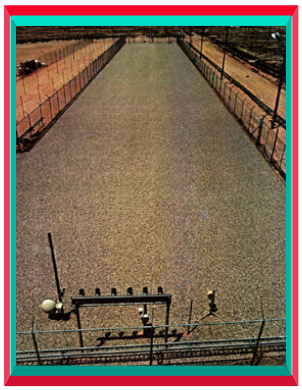
Intrusion Detection Sensors

Perimeter Sensor Technologies

- Ported Coax
- Fiber Optics
- Fence Disturbance
- Taut Wire
- E-field or Capacitance
- Active Infrared
- Passive Infrared
- Microwave
- Dual Technology Sensors
- Video Motion Detectors



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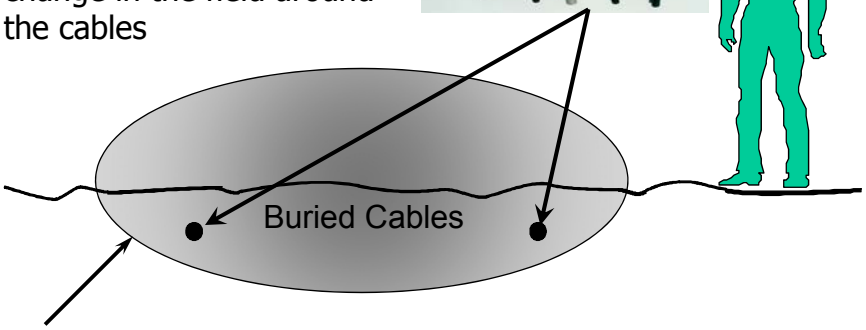
Intrusion Detection Sensors

Ported Coax Sensor

- Intruder approaching buried cables causes a change in the field around the cables



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Intrusion Detection Sensors

Fiber Optic Fence Disturbance Sensor

- Fiber optic sensors are most commonly used as fence disturbance sensors
- The sensor detects vibrations associated with climbing the fence or cutting the fence

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Intrusion Detection Sensors

Fence Disturbance Sensors

- Many different methods are available to detect vibrations on a fence. In addition to fiber optics, the following types of sensors can be used:
  - Inertia switches
  - Strain sensitive cable
  - Geophones
  - Piezoelectric sensors
- Most fence disturbance sensors use an event counter and a time window to minimize nuisance alarms

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Intrusion Detection Sensors

Taut Wire Fence

- Horizontal wires are monitored for movements associated with cutting and climbing the fence
- Sensing is accomplished with mechanical switches, strain gages, piezo-electric crystals, resistive rubber, or other materials

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Intrusion Detection Sensors

Electric Field Sensors

- Some wires transmit a small signal that other wires receive
- Coupling between the wires is changed by a person approaching the sensor

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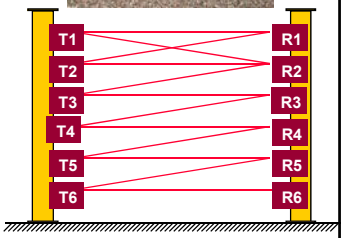
Intrusion Detection Sensors

Active Infrared Sensor System

- Multiple beams of infrared light are sent between the transmitters and the receivers
- Transmitters and receivers are stacked in various ways to create an array of beams
- Detection occurs when one or more of the beams is blocked



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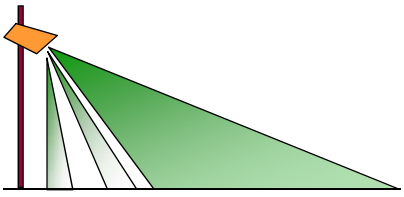
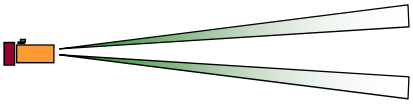
Intrusion Detection Sensors

Passive Infrared Sensor

- Lens divides detector into segments that are monitored for changes in heat energy
- Alarm occurs when changes in heat are detected in more than one segment in a short period of time



Side View



Top View

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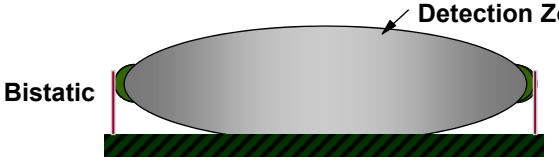
Intrusion Detection Sensors

Microwave Intrusion Detection Sensor

- Transmitter and receiver are located at opposite ends of the sector
- Transmitter sends a signal to the receiver
- Received signal consists of direct beam and reflected signals
- Alarm occurs when signal is disturbed by the intruder
- Sensors must be overlapped to provide a continuous line of detection

Stacked Bistatic Microwaves



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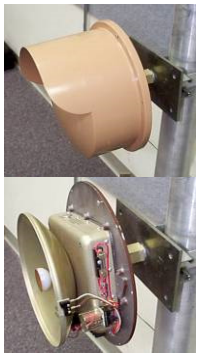
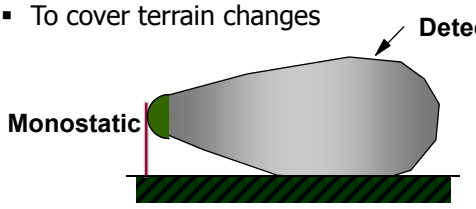
Intrusion Detection Sensors

Monostatic Microwave Sensor

- Transmitter and receiver share antenna
- Movement in the detection zone causes a frequency shift in the returned signal
- Used to provide additional coverage
  - In areas near entry portals
  - To supplement bistatic microwaves at overlap areas
  - To cover terrain changes





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Intrusion Detection Sensors

Dual Technology Sensors

- Reduces the number of nuisance alarms
- "AND" output
- Allows sensitivity to be set higher than for individual sensors
- Example:
  - Monostatic microwave and passive infrared

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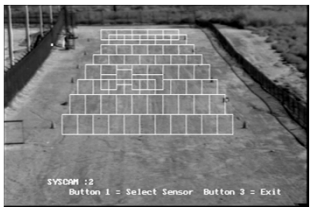
Intrusion Detection Sensors

Video Motion Detectors (VMD)

- VMD monitor a scene for changes and movement
- Early systems divided the screen into small blocks in the field of interest
- Newer systems can
  - Analyze individual pixels
  - Detect when an intruder
    - Crosses a certain line
    - Enters a certain area
    - Travels in a certain direction



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Intrusion Detection Sensors

Conditions That Can Adversely Affect Exterior Sensors

Extreme weather

Animals and other nuisance sources

Terrain, soil, and ground covering

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Intrusion Detection Sensors

Exterior Sensor Classification

	Passive or Active	Covert or Visible	LOS or Terrain Following	Volumetric or Line Detection
Buried Line				
Ported Coax	**A**	**C**	**TF**	**VOL**
Fiber Optic Cables	**P**	**C**	**TF**	**L**
Fence Associated				
Fence Disturbance	**P**	**V**	**TF**	**L**
Sensor Fence	**P**	**V**	**TF**	**L**
Electric Field	**A**	**V**	**TF**	**VOL**
Freestanding				
Active Infrared	**A**	**V**	**LOS**	**L/VOL**
Passive Infrared	**P**	**V**	**LOS**	**VOL**
Bistatic Microwave	**A**	**V**	**LOS**	**VOL**
Dual Technology	**A**	**V**	**LOS**	**VOL**
Video Motion	**P**	**C**	**LOS**	**VOL**

LOS= Line of Sight

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Intrusion Detection Sensors

Extended Detection

- Used to extend detection beyond Protected Area into Limited Access Area and possibly beyond
- Areas covered may
  - Be natural terrain with native vegetation and not well lighted
  - Contain more wildlife
- Alarm assessment may require thermal cameras or dispatch of patrols
- Contributes to Defense-in-Depth
- May be used as a compensatory measure to adapt to changes in threat and can help detect stand-off attacks

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Intrusion Detection Sensors

Seismic and Magnetic Sensors

- Seismic Sensors
  - Designed to detect footsteps
  - Types
    - Geophones
    - Pressure filled tubes
    - Buried fiber optics
- Magnetic Sensors
  - Detect intruders carrying weapons, tools, keys, or other metallic objects
  - Magnetic sensors are not commonly used in perimeter applications, because the detection range cannot be well controlled

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Intrusion Detection Sensors

Extended Detection Technologies

- Used to cover areas outside perimeter
  - Radar
    - Long-, medium-, and short-range
  - Laser Radar
  - Scanning Thermal Imagers
  - Unattended Ground Sensors

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Intrusion Detection Sensors

Interior Sensors

- Used to provide detection for protection against sabotage and unauthorized removal
  - Protected Areas
  - Inner or Vital Areas
- Help provide Detection in Depth
- Useful for detecting Insider activity
  - Can help enforce the Two Person Rule
- In addition to providing detection for access to nuclear materials, interior sensors are also used to protect sensitive information

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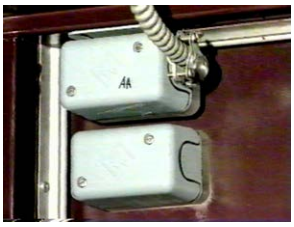
Intrusion Detection Sensors

Classification of Interior Sensors

- Active or passive
- Covert or visible
- Volumetric or line
- Mode of application
  - Boundary penetration
  - Interior motion
  - Proximity



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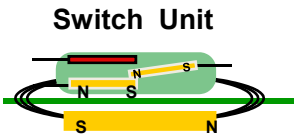
Intrusion Detection Sensors

Simple Magnetic Door Switch

- Switch mounted to door frame
- Magnet moves with door
- Detects opening of door



(Door Closed)

(Door Opened)

Non-Mag =

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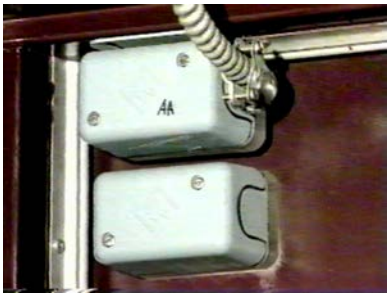
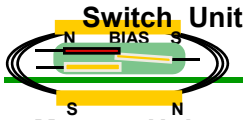
Intrusion Detection Sensors

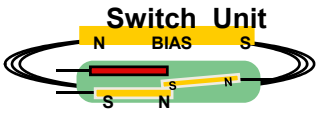
Balanced Magnetic Switch (BMS)

- Balanced magnetic switch contains a bias magnet in the switch housing
- Complex magnetic switch contains multiple reed switches and multiple magnets





Magnet Unit
(On Door)
(Door Closed)



(Door Opened)

Non-Magnetic =

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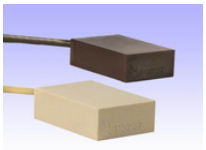
Intrusion Detection Sensors

Glass Break Sensors

- Acoustic glass break sensors
  - Mount on ceiling or wall
  - Respond to low frequency impact and higher frequencies of glass breaking
- Vibration glass break sensors
  - Mount directly on glass pane
  - Respond to vibration of breaking glass

- Magnetic switches are sometimes used to detect window opening



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Intrusion Detection Sensors

Boundary Sensors

- Break wire sensors sometimes used to detect penetration through a vent or window screen
- Vibration sensors mounted on walls to provide early warning of attempted penetration
- Jiggle switches, inertia switches, piezoelectric sensors can be used
- Many fence disturbance sensors, including fiber optic sensors, can also be used

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Intrusion Detection Sensors

Active Infrared

- Can be used across windows and doors to detect penetration or entry
- Detects a break in one or more beams of infrared light
  - Multiple transmitters and receivers form a vertical fence
  - Pulsed synchronous techniques can reduce interference and attempted defeat from external light sources
- May be used with entry control systems to ensure only one person entered

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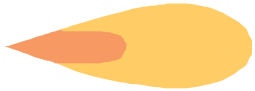
Intrusion Detection Sensors

Microwave Sensors

- Used to provide volumetric detection within a room
- Monostatic configuration
  - Single antenna or two antennas located in the same housing used to transmit and receive
  - Detection is based on the Doppler frequency shift between the transmitted and received signal caused by an object moving within the energy field
  - Most sensitive to movement toward or away from sensor



Manufacturer's representation of maximum and minimum detection patterns. Actual size can change due to sensor settings

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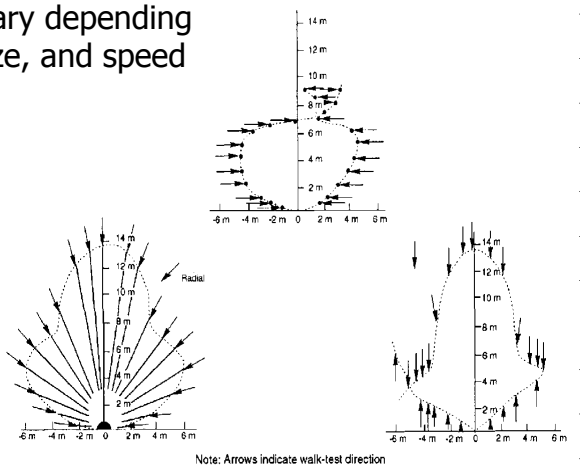
Intrusion Detection Sensors

Monostatic Microwave Actual Walk Test Detection Data

- Actual data can vary depending upon direction, size, and speed of intruder



Note: Arrows indicate walk-test direction

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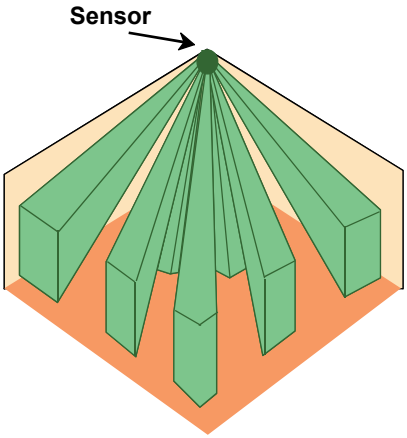
Intrusion Detection Sensors

Passive Infrared Sensors

- Detects changes in thermal energy
  - Pyroelectric detector converts changes in thermal energy to an electrical signal
  - Lens or mirror focuses energy onto pyroelectric detector
    - Determines field of view (detection volume)
    - Segmented to create multiple detection areas
  - Most sensitive across field of view



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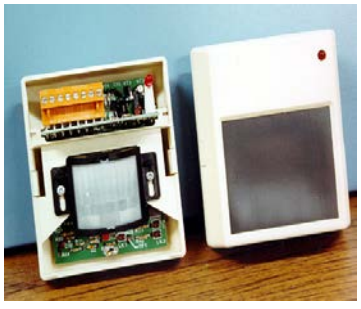
Intrusion Detection Sensors

Passive Infrared

- Many varieties of detection patterns are available
- Range from a narrow curtain detection pattern to a 360-degree ceiling mounted version



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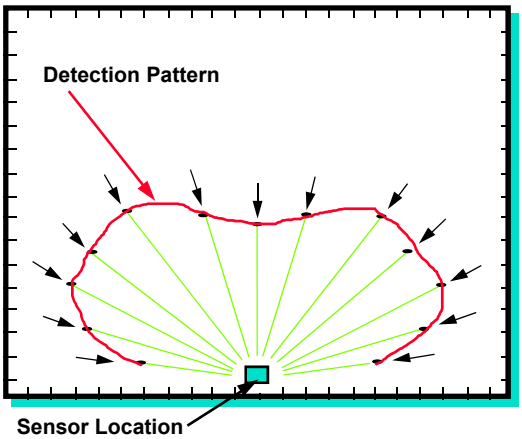
Intrusion Detection Sensors

Passive Infrared Sensor Walk Test Pattern

- Movement is towards the sensor
  - Least sensitive direction



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Intrusion Detection Sensors

Dual Technology Sensors

- Combines passive infrared and microwave technologies into one sensor unit
  - "AND" configuration
    - Both sensor technologies must detect motion
    - Combined P_D is less than each individual sensor
    - Reduces nuisance alarms
  - "OR" configuration
    - Either technology can generate an alarm output
    - Higher P_D
    - Higher nuisance alarm rate – either technology can generate nuisance alarms

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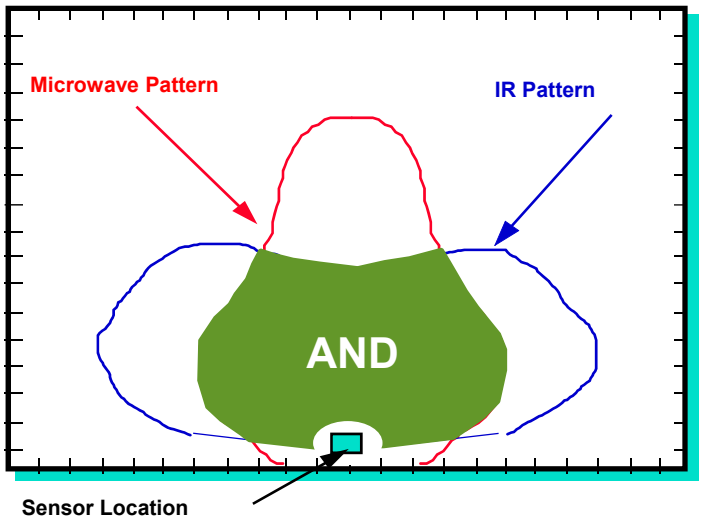
Intrusion Detection Sensors

Dual Technology Walk Test Patterns



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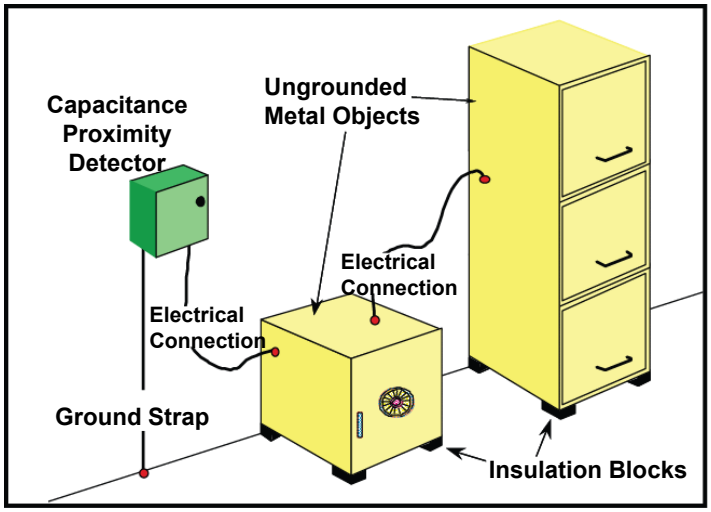
Intrusion Detection Sensors

Capacitance Proximity Sensor



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Intrusion Detection Sensors

Features of Good Interior Intrusion Detection System

- High P_D
- Low nuisance alarm rate
- Uses protection-in-depth
- Detects tampering
- Is properly installed: No loose mountings, wiring in conduit, proper location for sensors
- Well maintained
- Regularly tested

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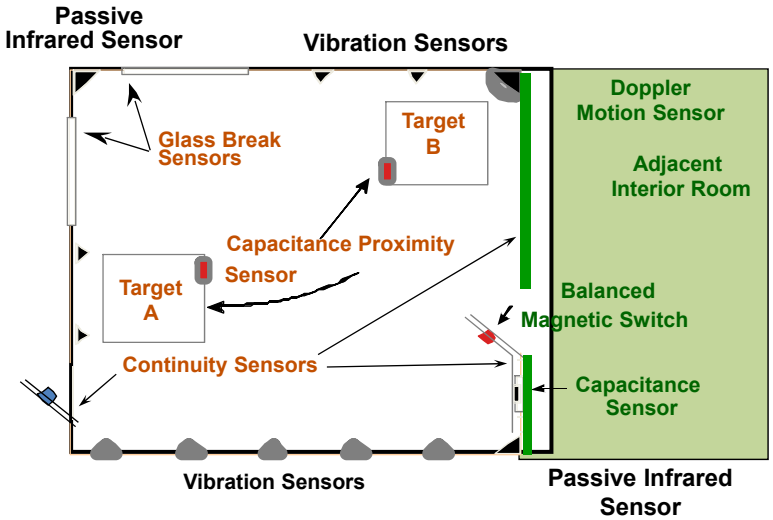
Intrusion Detection Sensors

Example Sensor Layout



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Intrusion Detection Sensors

Protection-in-Depth

Building
- Boundary detection (walls, windows doors)
- Volumetric detection (rooms, halls)
- Proximity detection (target)

Perimeter
May have some combination of:
- Volumetric sensors
- Line sensors
- Buried sensors

Early Warning (outside perimeter)

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Intrusion Detection Sensors

Features of Good Perimeter Sensor System

- Continuous line of detection
- Protection-in-depth
- Complementary sensors
- Clear zone
- Sensor configuration
- Site-specific system
- Tamper indication
- Integration with
  - Assessment system
  - Barrier delay
- Maintenance and testing program

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Intrusion Detection Sensors

Sensor Selection Considerations

- Application
- Operating principle
- Detection capabilities
- Conditions for unreliable detection
- Typical defeat methods
- Major causes of nuisance alarms

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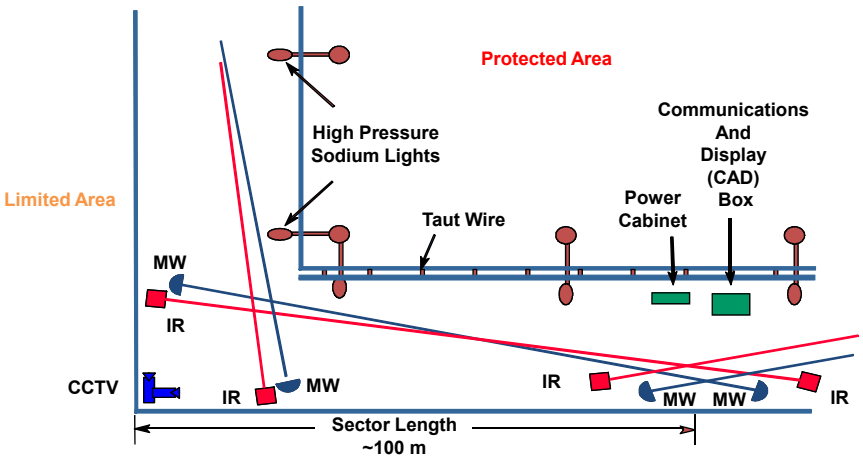
Intrusion Detection Sensors

Schematic of a Perimeter System



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Intrusion Detection Sensors

Example Perimeter System

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Intrusion Detection Sensors

Summary

- Performance characteristics
  - P_D, nuisance alarm rate, vulnerability to defeat
- Sensor classifications
  - Passive or active; covert or visible; line of sight or terrain following; volumetric or line detection; and by application
- Exterior technology includes
  - Buried line sensors, fence-associated sensors, freestanding sensors
- Interior technology includes
  - Boundary penetration, interior motion, and proximity
- Designers should consider
  - Design goals, effects of physical environmental conditions, and interaction of system with a balanced PPS

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